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TITLE OF THE INVENTION

Air Discharge Valve For An Aircraft

PRIORITY CLAIM

This application is based on and claims the priority under 35 U.S.C. §119 of German Patent Application 103 13 729.7, filed on March 27, 2003, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates to air discharge valves for an aircraft. Such valves are installed in an air outlet through the body wall of the aircraft for controlling the air pressure inside the aircraft body.

BACKGROUND INFORMATION

It is known to construct such valves for recovering a certain thrust generated because the pressure Pi inside the aircraft is higher than the pressure Pa outside the aircraft. Conventional flap valves of this type comprise one or several flaps. The

position of these valve flaps or gates relative to a valve opening is controllable by a drive mechanism inside the aircraft. The drive is normally controlled in closed loop fashion by a feedback control. The flap normally stays open or the flaps normally stay open as long as there is a positive pressure difference between the air pressure inside the aircraft and the atmospheric pressure outside the aircraft. Depending on the position of the flaps, particularly if the flaps are closed, the internal pressure inside the aircraft may be adjusted to provide a negative differential pressure. The valve flaps generally have plane surfaces or edges for forming an air discharge gap and outwardly facing surfaces adapted to the aircraft contour.

German Patent Publication DE 197 13 125 A1 (Steinert et al.) discloses a stage valve that has a first smaller stage (20) and a second larger stage (30). The first valve stage (20) and the second valve stage (30) are coupled with a drive gear (40) in such a way that the first smaller valve stage can be operated separately from the second larger valve stage. In one conventional embodiment the smaller valve stage has a centrally journaled flap mounted within an opening of a larger flap. In the other conventional embodiment a larger flap and a smaller flap are each centrally journaled. Thrust recovery is accomplished in each conventional version, particularly during cruising flight when the internal cabin pressure is substantially larger than the external atmospheric pressure at cruising altitudes. In the other conventional embodiment one flap (70) has a bulging broadened end (73) for diverting the air stream

onto a guide plate (76). The valve stages are supposed to have aerodynamically beneficial characteristics. However, a nozzle for the air discharge is not formed. Just air discharge channels are formed.

US Patent 3,426,984 (Emmons) discloses an aircraft pressurization outflow valve with two flaps each hinged at its end opposite the flap end edges (40, 42) that form an air outflow gap. These flap end edges (40, 42) form a convergent or convergent-divergent nozzle for effectively recovering thrust from the air discharging out of the cabin into the airstream around the aircraft outer body skin.

Further conventional air discharge valves similar to the above described valves are illustrated in present Figs. 1, 2 and 3. Fig. 1 shows an air discharge valve installed in the airbus model "320/A340". Fig. 2 shows an air discharge valve installed in the aircraft model "Boeing 777". Fig. 3 shows an air discharge valve installed in the aircraft model "Boeing 737". These conventional valves function as pressure control valves operating in response to a closed loop control signal.

Conventional valves as described above leave room for improvement particularly with regard to noise reduction, particularly in the below critical pressure range. Conventional valves also leave room for improvement with regard to making the thrust recovery more efficient, particularly for a positive pressure difference

ΔP when the internal pressure Pi is larger than the external pressure Pa.

OBJECTS OF THE INVENTION

In view of the foregoing it is an aim of the invention to achieve the following objects singly or in combination:

to construct a pressure regulating air discharge valve for an aircraft in such a way that the flow conditions into the valve, through the valve, and out of the valve are substantially improved;

to improve the thrust recovery generated by air flowing out of the aircraft body; and

to noticeably reduce the air flow noise of the air flowing out of the aircraft body into the surrounding atmosphere.

SUMMARY OF THE INVENTION

The above objects have been achieved according to the invention by an air discharge valve comprising a first valve flap having a first wedge-shaped sectional configuration with a first leading edge facing in said flight direction and a first trailing edge facing opposite said flight direction, a first journal journalling said first valve flap (1) to said aircraft body at a point closer to said first trailing edge than to said first

leading edge, a second valve flap having a second wedge-shaped sectional configuration with a second leading edge facing in said flight direction and a second trailing edge facing opposite said flight direction, a second journal journalling said second valve flap to said aircraft body at a point closer to said second leading edge than to said second trailing edge, at least said first leading edge having a curved sectional configuration, said first journal and said second journal being spaced from each other in said flight direction to provide an overlap area between said first and second valve flaps, a nozzle neck formed between a first facing surface of said first valve flap and a second facing surface of said second valve flap, said facing surfaces facing each other at least partially, a nozzle inlet converging toward said nozzle neck, a nozzle exit diverging away from said nozzle neck along said overlap area, said converging nozzle inlet and said diverging nozzle exit together forming a nozzle length in an air flow direction.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be clearly understood, it will now be described in connection with example embodiments thereof, with reference to the accompanying drawings, wherein:

Figs. 1, 2 and 3 show schematically conventional valves as described above;

Fig. 4 illustrates a schematic side view of an air discharge valve according to the invention in an open position; and

Fig. 5 illustrates symbolically a view in the flight direction into a nozzle exit formed by two valve flap surfaces facing each other and having a concave cross-sectional configuration.

DETAILED DESCRIPTION OF A PREFERRED EXAMPLE EMBODIMENT AND OF THE BEST MODE OF THE INVENTION

Fig. 4 shows a side or end view of two valve flaps 1 and 3 forming the present valve. A closed loop flap drive mechanism is not shown since such a drive is conventional.

The valve according to the invention shown in Fig. 4 comprises an inner valve flap 1 and an outer valve flap 3. The terms "inner" and "outer" have reference to a longitudinal central axis of an aircraft body 14 merely shown symbolically. Flap 1 is positioned more radially inwardly of the aircraft body 14 than flap 3. The interior pressure Pi prevails inside the aircraft body 14. The exterior pressure Pa prevails outside of the aircraft. Each valve flap 1 and 3 has a wedge-shaped sectional configuration formed by a body that substantially has a prism shape 12. The first or inner flap 1 has a leading edge 8 facing in the flight direction FD as defined by the aircraft body 14.

External air flows in a direction AFD opposite to the flight direction. The first or inner flap 1 has a trailing edge 8A and is hinged by a journal 2 to the aircraft body 14. The journal 2 is positioned closer to the trailing edge 8A than to the leading edge 8 of the flap 1. The leading edge 8 forms part of or is attached to a lateral narrow prism or wedge surface 12A and has a curved sectional configuration with a radius R that is preferably a single radius of a circle. However, the leading edge 8 having the curved sectional configuration, may also be formed by several radii depending on the desired aerodynamic shape of the leading edge 8. Additionally, the first or inner flap 1 has a radially inwardly facing wedge surface 10 and a radially outwardly facing wedge surface 11.

The second flap 3 has a construction similar to that of the first flap 1. More specifically, the second flap 3 also has a wedge-shaped sectional configuration with an inwardly facing surface 15 and an outwardly facing surface 16 and further including a leading edge 9 and a trailing edge 9A. The second leading edge 9 is preferably also aerodynamically shaped. However, the shape or cross-sectional configuration of the second leading edge 9 is not as critical as the aerodynamic shape of the leading edge 8 of the first flap 1 because the leading edge 8 forms part of a lead-in funnel into a nozzle inlet 6.

The second flap 3 is also hinged to the aircraft body 14 by a journal 4 positioned closer to the leading edge 9 than to the trailing edge 9A. An arrow 21 indicates the tilting motion of

the flap 1 about the hinge 2 in response to the control or drive of the above mentioned closed loop drive mechanism not shown. Similarly, the arrow 41 indicates the tilting motion of the flap 3 about the journal 4 in response to the operation of the drive mechanism.

The first journal 2 and the second journal 4 are spaced from each other in the flight direction FD and the first and second flaps 1 and 3 are so dimensioned, that an overlap area is formed between the leading end of the first flap 1 and the trailing end of the second flap 3. When the flaps 1 and 3 are in the open position as shown in Fig. 4, a nozzle neck S is formed between the two flaps. The above mentioned nozzle inlet 6 is formed between the leading edge 8 of the first flap 1 and the inwardly facing surface 15 of the second flap 3. The nozzle inlet 6 converges toward the nozzle neck S. A nozzle exit 7 is formed downstream of the nozzle neck S by a facing surface portion 11A of the first flap 1 and by a facing surface portion 15A of the second flap 3. The surfaces 11 and 15 and their respective portions 11A, 11B and 15A, 15B are referred to as facing surfaces because these surfaces face each other at least in the overlap area formed by the nozzle inlet 6 and the nozzle outlet 7. The air flowing out of the nozzle exits 7 indicated by the arrows 51 generates a thrust indicated by the arrow T since in the nozzle the several air flows 5 are integrated or consolidated into a single air flow 51 that is accelerated in the nozzle to at least a sonic velocity preferably to a supersonic velocity that depends on a critical ratio of the external pressure Pa to the internal

pressure Pi. This critical pressure ratio $(Pa/Pi)_{crit}$ is approximately 0.527. Thus, $(Pa/Pi) \leq (Pa/Pi)_{crit} \approx 0.527$.

According to the invention the thrust recovery is more efficient than the trust recovery of conventional valves because the aerodynamic configurations of the valve flaps, particularly in the overlapping area have a length in the air flow direction AFD sufficient for preventing flow separation from said first and second facing surfaces and for avoiding vortex formations particularly along the curved sectional configuration of the leading edge 8 of the first flap 1 to thereby reduce noise generation.

The efficient aerodynamic characteristics of the present valve are further enhanced by the fact that a downwardly and outwardly facing surface portion 11B of the flap 1 and an inwardly facing surface portion 15B of the flap 3 form air guide surfaces. More specifically, the downwardly facing surface 11B forms a guide surface for the air flow 51 out of the nozzle exit 7. The surface portion 15B forms a guide surface for the air flow 5 into the nozzle entrance 6. Thus, flow separation and vortex formation are substantially avoided upstream and downstream of the Laval nozzle 6, S and 7. Minor vortex formation that does not adversely affect the thrust recovery may be tolerated.

Preferably, the nozzle neck S is positioned where the curvature of the leading edge 8 of the first flap 1 merges into the downwardly facing surface portion 11A of the flap 1. This point

and thus the nozzle neck S is aligned with the prism lateral surface 12A.

According to the invention the two flaps 1 and 3 may also be referred to as the AFT gate and the forward (FWD) gate respectively as viewed relative to the flight direction FD. The shape of the Laval nozzle is maintained according to the invention due to the overlap area between the forward valve flap 3 and the AFT valve flap 1 even if these flaps are moved relative to one another as long as the above mentioned pressure ratio condition $(Pa/Pi) \leq (Pa/Pi)_{crit}$ is maintained or at least as long as the closed loop controlled position of the two flaps 1 and 3 is within a flap positional range that is customary during cruising flight. Stated differently, motions of the flaps shall not adversely influence the Laval shape of the overlap area so that the at least sonic or preferably supersonic speed of the exiting airstream 51 is not adversely influenced. Motions of the flaps relative to each other primarily vary the cross-sectional area of the nozzle neck, but the Laval nozzle configuration is maintained for motions of the flaps within the above mentioned range that is sufficient for all practical purposes to prevent flow separation from the first and second facing surfaces, for avoiding vortex formations along the walls of the nozzle, particularly along the curved sectional configuration of the leading edge 8 of the first flap 1 and for reducing noise generation. Moreover, this nozzle configuration assures that a maximal or optimal energy is converted into the thrust T by the air exiting from the nozzle exit 7.

By avoiding flow separation and vortex formations, the efficiency of the air discharge controlled in closed loop fashion is substantially improved compared to the above described prior art because the formation of an undisturbed supersonic flow not only reduces noise, but also results in a more efficient air discharge.

In a preferred embodiment the outwardly facing surface portions 11B of the first flap 1 and the outwardly facing surface portion 16 of the second flap 3 are formed with an aerodynamic surface that merges into the outer surface configuration of the skin of the aircraft body.

It has been found that a semicircular cross-sectional configuration of the leading edge 8 of the first valve flap 1 form an efficient air-inlet funnel for guiding the air flows 5 into the nozzle inlet 6 which is formed by the curved sectional configuration of the leading edge 8 and by the facing portion 15B of the inwardly facing surface 15 of the second flap 3.

Referring further to Fig. 4, the surface portions 15A and 15B together form an uninterrupted flat air guide surface upstream of the nozzle inlet 6, along the nozzle inlet 6, at the nozzle neck S and downstream of the nozzle neck along the overlap area that forms the diverging nozzle outlet 7. The displacement of the two flaps 1 and 3 in the flight direction relative to each other forms an efficient air lead-in guide that also contributes

to avoiding particularly vortex formation in the lead-in area forming the nozzle inlet 6.

Fig. 5 shows symbolically an embodiment in which the facing surfaces of flaps 1' and 3' are concavely curved to form the nozzle inlet 6 and the nozzle outlet 7 except the nozzle neck S which is shown in the closed position in Fig. 5.

Although the invention has been described with reference to specific example embodiments, it will be appreciated that it is intended to cover all modifications and equivalents within the scope of the appended claims. It should also be understood that the present disclosure includes all possible combinations of any individual features recited in any of the appended claims.